

Dental Biometrics: Human Identification Using Dental Radiograph

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Dental Biometrics: Human Identification Using Dental Radiograph

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by

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based on research carried out

under the supervision of

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Supervisor's Certificate

This is to certify that the work presented in the dissertation entitled *Dental Biometrics: Human Identification Using Dental Radiograph* submitted by *Rohit Raj*, Roll Number 711CS2165, is a record of original research carried out by him under my supervision and guidance in partial fulfillment of the requirements of the degree of *Master of Technology in Computer Science and Engineering*. Neither this thesis nor any part of it has been submitted earlier for any degree or diploma to any institute or university in India or abroad.

Dr. Sambit Bakshi

Dedication

I dedicate my thesis to my beloved parents..... .

The reason of what I became today.

Without whom none of my success would be possible.

Thanks for your great support, guidance, continuous care and love.

Signature

Declaration of Originality

I, *Rohit Raj*, Roll Number *711CS2165* hereby declare that this dissertation entitled *Dental Biometrics: Human Identification Using Dental Radiograph* presents my original work carried out as a postgraduate student of NIT Rourkela and, to the best of my knowledge, contains no material previously published or written by another person, nor any material presented by me for the award of any degree or diploma of NIT Rourkela or any other institution. Any contribution made to this research by others, with whom I have worked at NIT Rourkela or elsewhere, is explicitly acknowledged in the dissertation. Works of other authors cited in this dissertation have been duly acknowledged under the sections “Reference” or “Bibliography”. I have also submitted my original research records to the scrutiny committee for evaluation of my dissertation.

I am fully aware that in case of any non-compliance detected in future, the Senate of NIT Rourkela may withdraw the degree awarded to me on the basis of the present dissertation.

May 20, 2016
NIT Rourkela

Rohit Raj

Acknowledgment

"God never ends anything on a negative; God always ends on a positive."

First of all, I am grateful to *The Almighty God* for establishing me to complete this thesis.

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This thesis is a dedication to them who did not forget to keep me in their hearts when I could not be beside them.

Abstract

Biometric is the science and innovation of measuring and analyzing biological information. In information technology, biometric refers to advancements that measures and analyzes human body attributes, for example, DNA, eye retinas, fingerprints and irises, face pattern, voice patterns , and hand geometry estimations, for identification purposes.

The primary motivation behind scientific dentistry is to distinguish expired people, for whom different method for recognizable proof (e.g., unique finger impression, face, and so on.) are not accessible. Dental elements survives most of the PM events which may disrupt or change other body tissues, e.g. casualties of motor vehicles mishaps, fierce violations, and work place accident, whose bodies could be deformed to such a degree, that identification even by a family member is neither desirable nor reliable.

Dental Biometric utilises dental radiographs to distinguish casualties. The radiographs procured after the casualty's demise are called post-mortem radiograph and the radiograph obtained when the casualty was alive is called ante-mortem radiograph. The objective of dental biometric is to match the unidentified individual's post-mortem radiograph against a database of labelled antemortem radiograph. If the teeth in the postmortem radiographs adequately matches the teeths in somebody's antemortem radiograph, the identity of the post-mortem radiograph is established. The dental radiographs give data about teeth, including tooth contours, relative positions of neighbouring teeth and states of the dental works. The proposed system has feature extraction and matching of dental images. Matching Process involves-

- Isolation of each tooth (Radiograph Segmentation).
- Contour Extraction or the Feature Extraction (crown shape and root shape).
- Contour matching (i.e. Alignment).

This thesis proposes a novel method for the contour extraction from dental radiographs. The proposed algorithm of Active Contour Model or the Snake model is used for this purpose. A correctly detected contour is essential for proper feature extraction. This thesis only works on the contour detection. The method has been

tested on some radiographs images and is found to produce desired output. However, the input radiograph image may be of low quality, may suffer a clear separation between two adjacent teeth. In that case the method will not be able to produce a satisfactory result. There is a need of pre-processing (e.g. contrast enhancement) before the active contour detection model can be applied.

Keywords: DentalRadiographs; Contour-Extraction; Ante-mortem; Post-mortem radiographs; Active Contour.

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Chapter 1

Introduction

Biometric is a science of perceiving the identity of an individual based on physiological and behavioral qualities of the subject. Biometric authentication have developed from the detriments of customary method for authentication. The issue with token-based Frameworks are that the ownership could be lost, stolen, overlooked or forgotten. The downsides of knowledge-based methodologies are that it is extreme for a man to recall troublesome passwords/PINs; actually, simple passwords can be speculated and broke by interlopers. In this way, the authentication framework blends token-based and knowledge-based authentication strategies, e.g. Automatic teller machine (ATM) hubs of banks confirm a person by taking ATM cards (token) alongside a mystery PIN (knowledge) as authentication inquiry. Be that as it may, the mix of knowledge and token based framework can not fulfill the security necessities. The essential point of preference of biometrics over token based and knowledge based methodologies is that it can't be lost, overlooked or stolen. Additionally, it is exceptionally troublesome to parody biometric characteristics as the individual to be verified should be physically present. A nonexclusive biometric framework works by taking contribution from the client, preprocessing the sign to denoise it to discover the locale of enthusiasm, removing includes, and validating an individual based on the consequence of examination . A biometric framework has three run of the mill working modes: enrolment mode, check mode, recognizable proof mode. In enrolment mode, the component from a subject is separated and put away in the database. Amid check mode, a subject is validated by contrasting live question biometric format and the database layout of the person whom the subject cases himself to be. The comparison in this mode is a one to one process. In identification mode, the framework takes live question format from the subject and ventures the whole database to locate the best-coordinate layout to recognize the subject. The examination in this mode is a one-to-numerous process. Various biometric qualities like face, iris, unique finger impression, walk, voice, face-thermograph, mark are of key exploration zone for some a scientists because of gigantic need of security in robotized frameworks. Watching fundamental nature of the attributes, two essential classifications can be distinguished

as: Physiological and Behavioral (or dynamic) biometrics . Physiological biometrics are based on direct estimation or information got from estimation of a part of the human body. A man is recognized by his/her face by someone else. Unique mark location is one of the age-old strategies utilized for perceiving the genuineness of a man. However iris design, retina tissue design, palmprint geometry have advanced as driving physiological biometrics with the advance of robotization of biometric acknowledgment framework. Behavioral qualities, then again, are based on a move made by a man. Behavioral biometrics, thusly, are based on estimations of information got from an activity, and in this way indirectly measure attributes of the human body. Voice acknowledgment, keystroke elements, and online/disconnected from the net mark are driving behavioral biometric characteristics. Reasonableness of an attribute as a biometric for functional usage is described by uniqueness, dependability, collectability, adequacy, simplicity to catch, non-intrusiveness and circumvention.

History of Biometrics The history of biometric methods goes back thousands of years, e.g., 500 B.C. in Babylon where fingerprints were recorded in clay tablets to be used as a person's mark for business transactions[1]. In scientific literature human identification using body measurements dates back to the 1870's when Alphonse Bertillon proposed a body measurement system including measures like skull diameter, arm and foot lengths. The system was used until the 1920's to identify prisoners in the USA. Quantitative identification through fingerprint and facial measurements was first proposed by Henry Faulds, William Herschel and Sir Francis Galton Herschel in the 1880's. The development of true biometric systems began to start in the second half of the 20th century coinciding to the development of new signal processing techniques. In the 1960's fingerprint and speaker recognition systems were researched followed by the development of hand geometry systems in the 1970's. Retinal, signature verification and face systems came up in the 1980's. In the 1990's the first iris recognition algorithm was patented and iris recognition became available as a commercial product. Biometric systems began to emerge in everyday applications in the early 2000's [1][2].

Classification of Biometric Characteristics A biometric characteristic can be described with five qualities [2] :

1. Robustness: The biometric characteristic should be stable and not change over time.
2. Distinctiveness: To clearly recognize an individual, the biometric characteristic should show great variation over the population.
3. Availability: The entire population should ideally have the measured biometric characteristic.

4. Accessibility: The biometric characteristic should be easily acquired using electronic sensors.
5. Acceptability: The process of acquiring biometric measurement should be easy and user friendly which means that people do not object to having this measurement taken.

Biometric systems can be divided into behavioral and physical (physiological) systems:

Behavioral biometric Behavioral biometrics are characterized by a behavioral trait that is learnt and acquired over time [3]. It is the reflection of an individual's psychology. Behavioral characteristics can change over time which means that a behavioral biometric system needs to be de-signed more dynamically and accept some degree of variability [4]. Physiological elements may influence the monitored behavior in specific behavioral biometric techniques, e.g. keystroke dynamics, signature verification and speaker verification [3].

Physical (physiological) biometric Physical biometrics are characterized by a physical characteristic rather than a behavioral trait, e.g. fingerprint, face or the blood vessel pattern in the hand [4]. It does not change over time which means it is more stable than a behavioral biometric. Behavioral elements may influence the biometric sample captured, e.g. tremor during a fingerprint acquisition [3].

The Biometric Process The biometric process is divided into five main stages:

1. Data collection: Capturing a biometric sample (raw information of a biometric characteristic before pre-preprocessing) from a petitioner, who needs to confirm his/her personality. If there is no reference layout in the database, the individual should first enroll the biometric feature (e.g. fingerprint) to be included into the database. This procedure is called enlistment or enrollment. If the individual is already enlisted, the procedure is called confirmation (check or ID) which implies setting up trust in reality of the determination [1].
2. Feature extraction: After the pre-preprocessing of the biometric sample, an algorithm extracts the extraordinary components or the unique features from the biometric sample and changes over it into biometric information with the goal that it can be coordinated to a reference layout in the database[3].
3. Template database: On account of enrolment, biometric information are put away in a template database. On account of validation, biometric information are matched against a reference format from the layout database.

4. Matching: In the matching stage, biometric information are matched (or compared) with information contained in one (confirmation) or more (ID) reference template(s) to score a level of likeness.
5. Deciding: The acknowledgment or dismissal of biometric information is subject to the scored level of comparability in the matching stage, falling above or beneath a characterized limit. The limit is flexible so that the biometric framework can be pretty much strict, depending upon the necessities of any given biometric application[3]. As shown in Figure 1.1

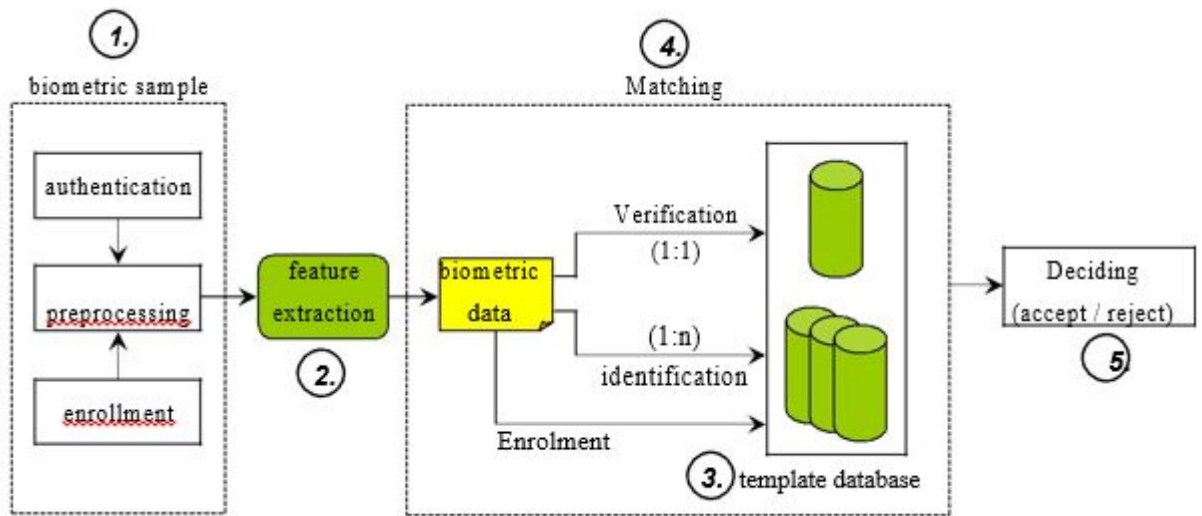


Figure 1.1: Model of the biometric process

1. Capturing of the biometric sample; 2. The biometric sample is converted into biometric data by extracting its unique features; 3. The reference templates are scored in the template database; 4. Matching of the biometric data with one or more reference template(s); 5. Acceptation or rejection of the claimant.

1.1 About Dental Biometrics

The fundamental motivation behind scientific dentistry is to distinguish the deceased person for whom other method for recognizable proof (e.g., face, fingerprint and etc) are not accessible. Dental biometric is the utilization of dental radiography (x-ray) in the recognizable proof of generally unidentifiable human remains. This scientific use has earned dental biometrics awesome distinction, as its utilization has showed up as much in crime novels and network shows as in this present reality of the crime lab. Tooth size, tooth contours and shapes, separation amongst teeth, and crowns, fillings, and other dental work all variable into the constructive distinguishing proof of persons from minor skeletal remains, or in instances of carcasses seriously blazed or

distorted. In this manner biometric examination of dentistry is a final resort strategy for ID when other more normal techniques come up short.



Figure 1.2: Human teeth
are often the only identifiable biometric attribute in forensic science.

1.1.1 Modern Methods of Computer-aided Dental Biometrics

Prior to the advancement of scientific calculations and picture honing and extraction techniques that permitted exceedingly dependable examination of dental radiographs on PC, the procedure was all the more moderate and dreary. The fundamentals still apply: two radiographs of proportional territories of the casualty's and a proposed applicant's teeth must be thought about fastidiously. To do this, prior records, presumably from the match applicant's dental practitioner, must be gotten, and another after death picture must be taken of the remaining parts of the casualty's teeth. Composed dental records will likewise add to the recognizable proof. In uncommon situations where an attacker has lost a tooth or crown or has left chomp blemishes on a casualty, dental biometrics can likewise be utilized to find the executioner.

There are four stages important in utilizing cutting edge innovation to perform exact biometric investigation of dentistry:

- A dental radiograph must be acquired from the casualty's remaining parts
- That image must be pre-processed to enhance visibility of picture elements
- Features must be exclusively separated from the full x-rays.
- A prior picture that has experienced the same procedure (steps one through three above) must be contrasted with the removed components with look for a match.

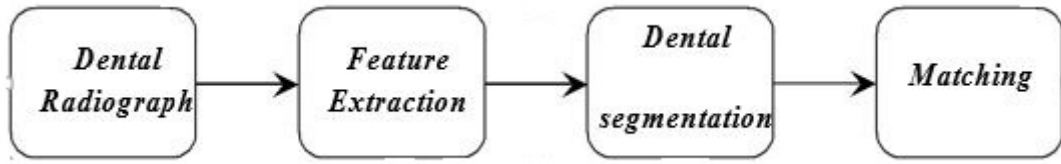


Figure 1.3: Block diagram of the proposed dental biometric method

1.1.2 Image pre-processing

Once a radiograph exists and has been transferred into the product framework, some underlying preparing is essential. Radiographs might be one of three sorts: bitewing, covering for the most part the above gum segment of teeth; periapical, demonstrating additionally the full root; or Panoramic, giving the expansive perspective of teeth and jaws. Periapical is favored for its nearby up perspective with all the tooth included. The product will take out unneeded foundation and center very close on the specific tooth, dental work, and so forth that is being referred to.

1.1.3 Feature Extraction

A biometric is a physical element or conduct that is quantifiable. Behaviors, for example, handwriting styles, gait of walk, and voice quality, alongside attributes like eye retinas, fingerprints, or the state of a tooth are biometrics. Dental biometric softwares shades teeth, bone, dental work, and foundation distinctively in order to separate individual things and components for later examination. Size, shape, and position of teeth in respect to other close-by teeth are focused alongside crowns, fillings, and all simulated dental installations. By expanding complexity and discovering edges, the product works at disconnecting each vital component. Binary distinction frequently works best for dental work, while a three-way shading plan is generally utilized for teeth.

1.1.4 Feature Matching

Pre-and post-mortem radiographs should now be deliberately analyzed. A decent programming system can process the relative likeness or distinction between databases stored images and present them in numbered structure. Size, separation measured amongst object, and faltness versus peakedness are considered. The level of skewing of the pre-demise x-ray away from the post-death x-ray will figure out whether a match is had. As a man's teeth is always showing signs of change, it can't be relied upon to ever get a 100% match, however coordinates that are inside a restricted edge of skewing are "considered" matches.

Dental biometrics is an old however now reformed science that keeps on helping in the distinguishing proof of obscure human remains. By pre-handling radiographs, separating sought elements, and looking at pre-and post-mortem depictions of a man's teeth and dental work, distinguishing proof is frequently conceivable where else it would not be.

1.2 Motivation

The importance of automatic dental identification has become apparent after the late catastrophes, for example, the 9/11 terrorists assault in United States of America in 2001 and Asian tsunami in 2004. The casualties bodies were seriously harmed and disintegrated because of flame, water, and other natural elements. As a result in most of the case common biometrics traits such as facial recognition , fingerprints, iris identification, and others were not present. Thatswhy dental features may be the only clue for the identification of the deceased people.

After the 9/11 assault, around twenty percent of the 973 casualties were distinguished in the primary year utilizing the dental biometric. Approx. 75% of the 2004 Asian Tsunami casualties in Thailand were related to the assistance of Dental records. Table [1] gives the correlation between the dental biometrics and other casualty's recognizable proof methodologies i.e. inner ID, outer ID, fortuitous ID and hereditary distinguishing proof . The quantity of casualties to be distinguished utilizing dental biometrics is regularly vast if there should arise an occurrence of debacle situations. However, the conventional manual distinguishing proof in light of scientific odontology is particularly tedious. For instance the quantity of Asian Tsunami casualties recognized amid the initial nine months was just 2,200 (out of an expected aggregate of 190,000 casualties).

The low viability of manual systems for dental ID makes it essential to make customized strategies for coordinating dental records.

Table 1.1: A comparison of evidence types used in victim identification

Identification approach	Circumstantial	Physical			
		External	Internal	Dental	Genetic
Accuracy	Medium	High	Low	High	High
Time for identification	Short	Short	Long	Short	Long
Antemortem record availability	High	Medium	Low	Medium	High
Robustness to decomposition	Medium	Low	Low	High	Medium
Instrument requirement	Low	Medium	High	Medium	High

1.3 Problem Definition

In the past many researchers have been trying to develop an automated dental biometric system for human identification. But till date No effective method has been developed. Dental Biometrics consist of the following steps:

- Dental Radiograph Collection.
- Dental Feature Extraction
- Matching

Contour extraction of teeth was the major challenge in this research, which is the first step towards developing the Dental Biometric System. Current research is an attempt towards developing a method for the “contour extraction of teeth”. After a desired output for the tooth radiograph (Contour), only we can proceed toward the next level of Dental Biometrics or the matching of the features.

Many problems were investigated out by the survey of the related existing literatures. These problems were a hindrance in this research. Some of them could be resolved by pre-processing or some other method but some problems like shape variation due to ageing cannot be eliminated.

The major problem were:

1. The teeth shape extracted from A.M radiographs are not very accurate because of image quality, i.e. the image is blurred or distorted.
2. The shape of the same tooth in A.M and P.M images may vary due to changes in the viewing angle or the imaging angle.
3. Tooth shape may vary because of ageing.

1.4 Performance Measures Used

The accuracy of a biometric system is determined through a series of tests. A complete evaluation of a system for a specific purpose is divided into three main stages before a biometric system can be used and the full operation begins :

1. Technology evaluation, where the accuracy of the matching algorithm is assessed.
2. Scenario evaluation, where the performance of the matching algorithm in a mock environment is tested.
3. Operational evaluation, where the biometric system is finally tested live on site.

1.4.1 Performance Testing Methods

To measure the performance of a biometric system, statistics are used:

False acceptance rate (FAR) The FAR is the rate of times, a framework creates a false acknowledge, which happens when a man is inaccurately matched to someone else's current biometric. Its worth is one, if all impostor formats (layouts of different persons) are dishonestly acknowledged and zero, if no impostor layout is accepted. The FAR is like the false match rate (FMR).

False rejection rate (FRR) The FRR is the rate of times, a system delivers a false reject, which happens when a man is not matched to his/her own current biometric layout. Its quality is one, if all authentic formats (layouts of the same individual) are falsely rejected and zero, if no genuine layout is rejected. The FRR is like the false non-match rate (FNMR), aside from the FRR includes the inability to obtain (FTA) rate and the FNMR does not. The FTA is the disappointment of a biometric framework to catch and/or separate usable data from a biometric test .

The five qualities of a biometric characteristic are quantified by the following measures [5]:

1. The robustness is measured by the FRR and is the percentage that the matching of a submitted biometric sample with an enrolled genuine template fails.
2. The distinctiveness is measured by the FAR and is the percentage that a submitted biometric sample matches with an enrolled impostor template.
3. The availability is measured by the failure to enroll (FTE). The FTE is the ace part of the number of inhabitants in inquirers, neglecting to finish enlistment

or enrollment. Normal disappointments incorporate end clients who are not appropriately prepared to give their biometrics, the sensor not catching data effectively, or caught sensor information of insufficient quality to build up a format.

4. The accessibility can be quantified by the throughput rate. The throughput rate is the number of claimants that a biometric system can process within a certain time interval .
5. The acceptability is measured by interviewing the claimants and analyzing the obtained results.

Out of the mentioned testing methods it cannot be said which biometric characteristic is the best. Their importance is highly dependent on the specific applications, the population and the used hardware/software system.

1.4.2 Performance Testing using ROC Analysis

The received metrics of the robustness and the distinctiveness are complexly correlated to each other but can be manipulated by using administration methods like thresholding.

Thresholding (False Acceptance / False Rejection) To compare two biometric templates, a matching score is calculated which represents their similarity. The higher the score, the higher is the comparability between them. The real scores (matching scores of certified formats) ought to dependably be higher than the impostor scores (matching scores of impostor layouts), which is ordinarily impractical in genuine biometric frameworks. A choice made by a biometric system is either a genuine type of decision or an impostor kind of choice, which can be represented by two statistical distributions called genuine distribution and impostor distribution. For every kind of decision there are two conceivable results: genuine or false. Therefore, there are an aggregate of four possible results: (i) a genuine individual is acknowledged, (ii) a genuine individual is rejected, (iii) an impostor is rejected, and (iv) an impostor is acknowledged. Results (i) and (iii) are right while (ii) and (iv) are inaccurate. To separate the two distributions, a classification threshold is chosen which leads to some classification errors.

The FAR, the FRR and the equivalent error rate (ERR) are utilized to demonstrate the identification precision of a biometric system, The EER is characterized as the point where the FAR and FRR meet and have the same value, The EER of a system

can be utilized to give a limit free execution measure. The lower the EER the better is the execution of the biometric system.

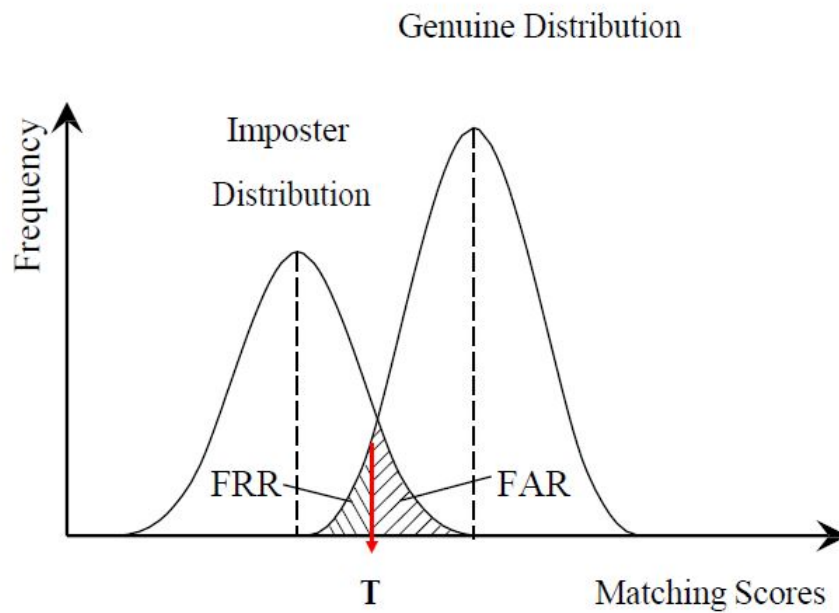


Figure 1.4: Score distributions of a simulated biometric system
.Score distributions for the impostor and genuine matching scores of a simulated biometric system. Given a matching score threshold (T), the area below T under the genuine distribution represents the FRR. The area above T under the impostor distribution represents the FAR

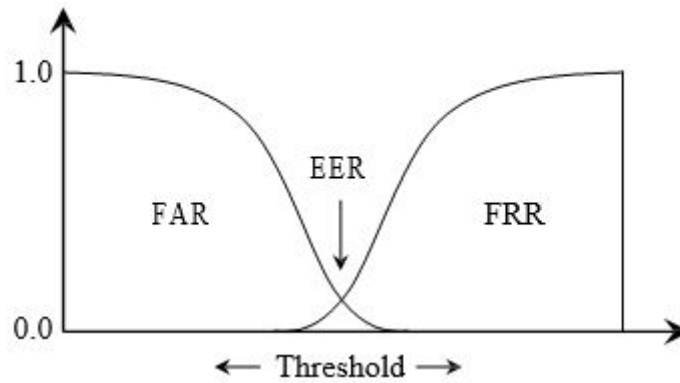


Figure 1.5: Values of the false acceptance rate (FAR) and the false rejection rate (FRR) for a varying threshold

1.4.3 Receiver Operating Characteristic (ROC) Curve

A Receiver Operating Characteristic (ROC) curve of a system represents the FRR and FAR for all edges. Every point on the ROC characterizes FRR and FAR for a specific edge. High security access applications are worried about break-ins and, subsequently, work with a limit at a point on ROC with little FAR. Measurable applications yearning to get a criminal even to the detriment of looking at a substantial number of false acknowledges and, subsequently, work with an edge at a high FAR. Civilian applications endeavor to work at operating points with both low FRR and low FAR, see Figure 1.6 [2].

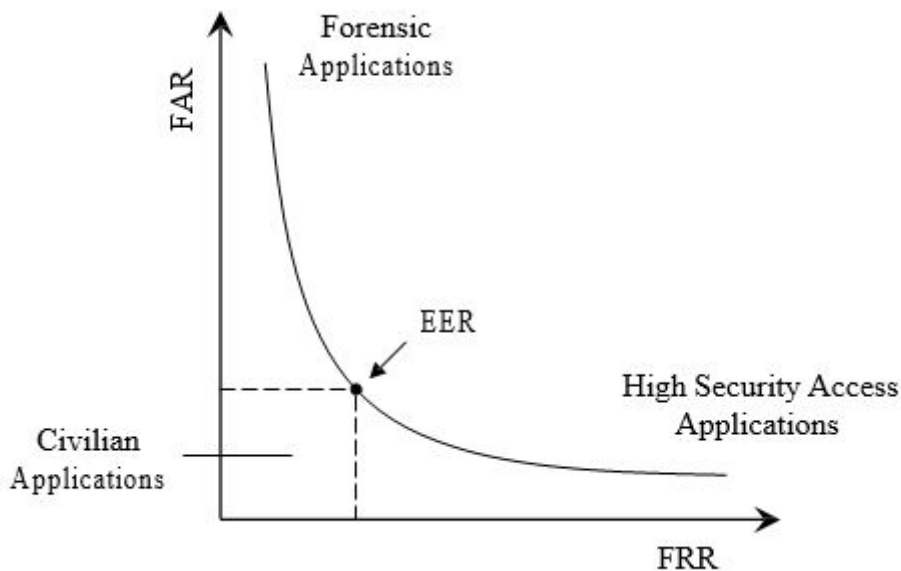


Figure 1.6: Receiver operating characteristic (ROC) curve
The point on the ROC curve where the FAR is equal to the FRR is represented by the EER

Creation of the ROC Curve To create the ROC curve of a biometric system, the genuine scores (matching scores of genuine templates) and the impostor scores (matching scores of impostor templates) are calculated and normalized in a way that the sum of all genuine scores and the sum of all impostor scores is one. To achieve the distributions for the genuine and impostor matching scores, the scores are commutatively summed up, see Figure 1.7.

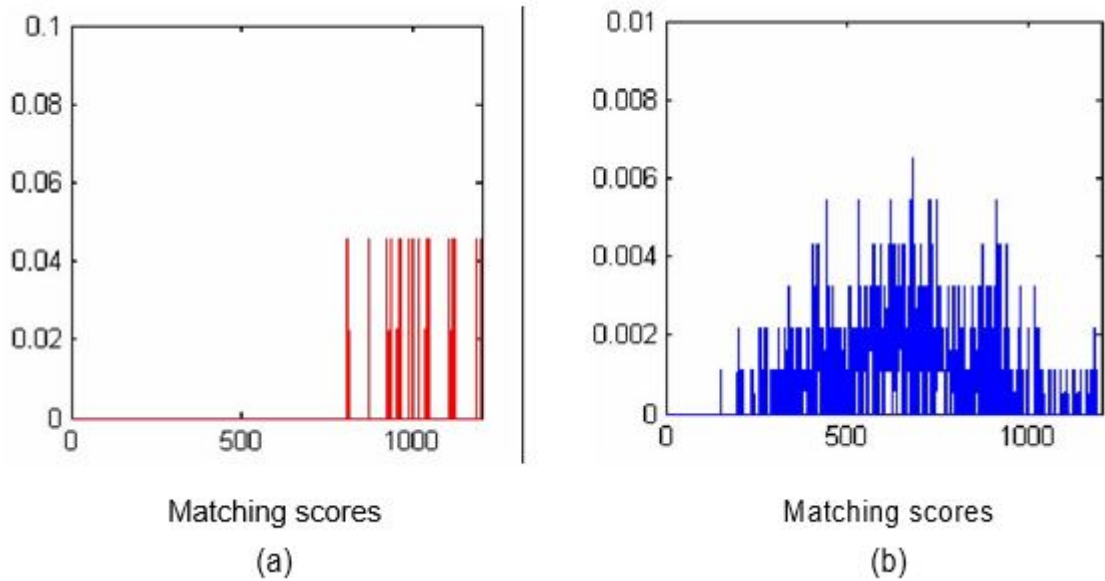


Figure 1.7: Matching scores for genuine and impostor templates
(a) genuine and (b) impostor templates

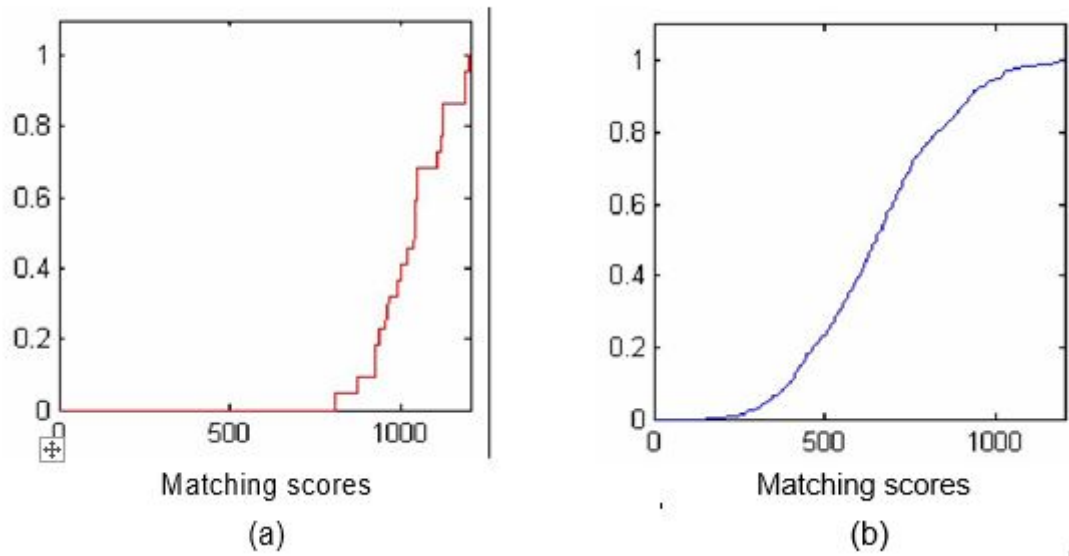


Figure 1.8: Distributions for genuine and impostor matching scores
 (a) genuine and (b) impostor matching scores

Finally, both distributions are displayed in one diagram. The complement of the impostor score distribution is calculated to visualize the threshold at the EER, see Figure 1.9(a). The ROC curve illustrates the FRR and the FAR for all thresholds in one diagram, see Figure 1.9(b).

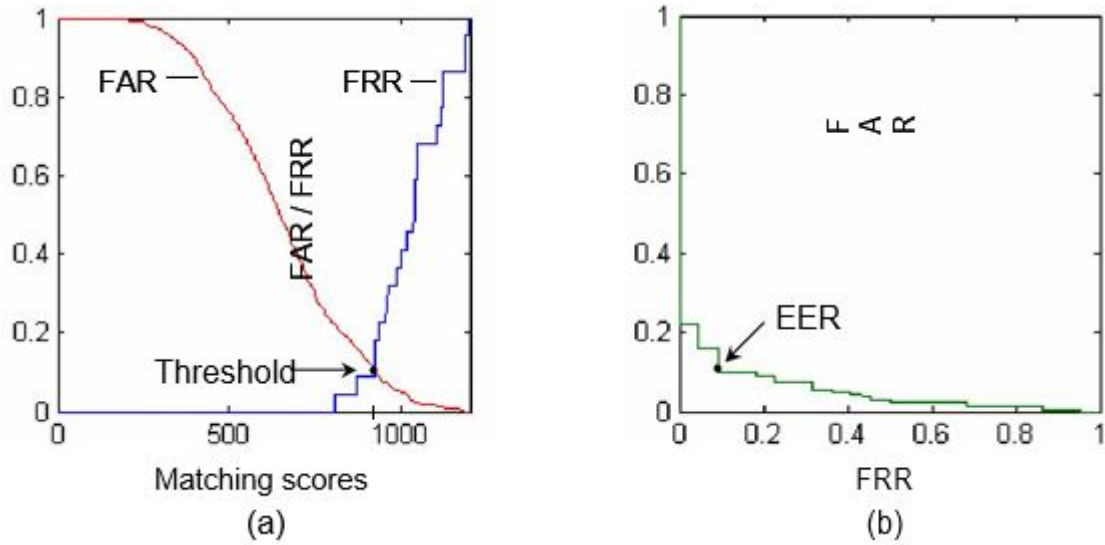


Figure 1.9: Created ROC curve

- (a) Genuine and impostor distribution in one diagram to visualize the threshold at the EER (Threshold=908). (b) The FAR versus the FRR in one diagram (EER=10.6).

1.4.4 Comparison of Biometric Systems

Two or more biometric systems cannot be compared if just one of the values FARs or FRRs are given. Both parameters have to be provided to compare the systems because in some cases, it is possible that the system with the lower FAR has an unacceptable high FRR and vice versa.

The values FAR and FRR are dependent on the selected threshold. As mentioned the EER can be used to give a threshold independent performance measure. Another method for a comparison is to calculate the area under the ROC curve (AUC).

Finally, to compare the results of two or more biometric systems, it is necessary that the compared EERs or AUCs values are calculated on the same test data using the same test conditions, e.g. the same test protocol [2][6].

1.5 Thesis Organization

The whole thesis comprises of three chapters following this chapter. The remaining thesis is organized as follows :

Chapter 2: Dental Biometrics and Related Works This chapter explains the various works carried in this field of Dental biometric. It also explains about the forensic odontology and issues related with it and its usage. A section of this chapter also describes the types of dental radiographs and the universal numbering system for the teeth. In the later section the summary of the literature survey of some papers are discussed.

Chapter 3: Proposed DRS using Active Contour Model This chapter discusses an approach to extract the tooth contour, as the shape of the tooth is not a simple geometrical shape so a simple curve wouldn't do this. The chapter proposes a modified version of the Active contour model or the snake model for the contour extraction of the tooth. It explains the snake algorithm , model of GVF snake, application and problem with the GVF snake. Lastly we have discussed the experimental results and the output which was carried out on some of the dental radiographs.

Chapter 4: Conclusion and Future Work This chapter concludes this thesis giving the analytical remarks on the overview of this research and the limitation of the proposed methodology and the scope for further research in this field.

Chapter 2

Dental Biometrics and Related Works

Dental biometrics automatically investigates dental radiographs to recognize expired people. There are two types of dental radiographs. radiographs gained after the death, postmortem (PM) radiograph, and radiographs obtained while the individual is alive, antemortem (AM) radiograph, see Fig 2.1. AM radiographs, marked with patient names, are gathered from the dental practitioner. The strategy utilized as a part of dental biometrics is coordinating unlabeled PM radiographs against a database of named AM radiographs. The identity of the PM radiograph is acquired, if the dental feature in a PM radiograph adequately matches with the dental features of the AM radiograph [7][8]

2.1 Forensic odontology

Forensic odontology (criminological dentistry) is the branch of legal sciences concerned with recognizing human people based of their dental elements and has a background marked by over two centuries. This includes connection with law implementation organizations charged with the responsibility of examining the evidence from cases including violent crime, elder abuse, child abuse,missing persons and mass calamity situations. Regardless of the possibility that lone somewhat dental data is accessible, a

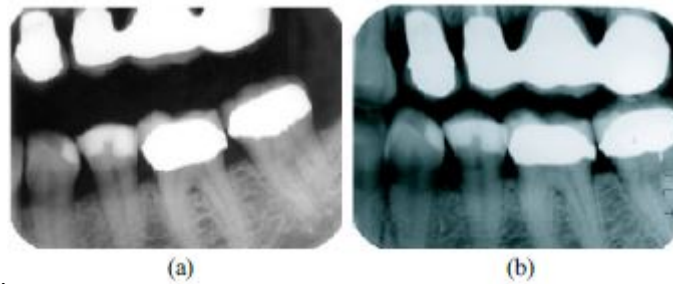


Figure 2.1: Ante-mortem (AM) and post-mortem (PM) radiograph of an individual

feeling can in any case be offered on age, propensities, oral cleanliness, and individual components which may match with antemortem records [9].

2.1.1 Categories of Dental Evidence

Different types of dental proofs in the field of forensic odontology are [10]:

- A tooth fragment or a single tooth.
- A section of a human jawbone.
- DNA obtained from a toothbrush, tooth, cigarette, etc.
- DNA obtained from a swabbing of bite marks, foodstuff or object that possesses saliva transfer evidence.
- Dental restorations and appliances that can be associated to an individual through specific dental material type, name inscriptions, unusual design or composition characteristics.

2.1.2 Legal Issues in Forensic Odontology

Radiology results are essential data in a dental practice and are considered as definitive evidence in court or identification cases. Since radiology is broadly used to record and assess the discoveries, it is likewise prescribed by United Nations, Interpol and American board of Forensic Odontology in examinations of mass graves, disasters and casualty and body identification [11]. The combination of restored, non-restored, missing, and rotted teeth can be as special as a unique mark and the likelihood of two dentitions being the same is low. This uniqueness takes into account dental correlation with be a legitimately adequate method for distinguishing proof, regardless of the fact that one and only tooth remains [12].

2.2 Teeth as Biometric characteristics

Behavioral qualities (e.g. signature or speech) and as well as most physical qualities are not appropriate for PM distinguishing proof. Particularly under extreme circumstances experienced in mass catastrophes (e.g. plane accidents, fires mishaps, and so on.) or when there is no recognizable proof conceivable inside a few weeks after death. In that case, a postmortem biometric feature needs to survive extreme conditions and oppose early decay that influences body tissues. Dental elements are viewed as the best possibility for PM distinguishing proof as a result of their survivability. Tooth shapes, appearances, tooth sections, metal rebuilding efforts,

skull and jawbone pieces may have highlights that can be connected with only one individual[10].

2.3 Universal Numbering System

The Universal Numbering System is a technique for distinguishing teeth and is approved by the American Dental Association. This strategy utilizes numbers with every tooth assigned by a different number from 1 to 32 [13]. Figure 2.2 illustrates the numbering system used on a standard dental chart for a full set of adult teeth.

The human permanent dentition is divided into four classes of teeth based on appearance and function or position [13]:

1. Incisors, are located in the front of the mouth and have sharp, thin edges for cutting. The lingual surface can have a shovel-shaped appearance.
2. Cuspids (canines or eyeteeth) are at the angles of the mouth. Each has a single cusp in stead of an incisal edge and are designed for cutting and tearing.
3. Bicuspid (premolars) are similar to the cuspids but they have two cusps used for cutting and tearing, and an occlusal surface to crush food.
4. Molars are situated in the back of the mouth. Their size slowly gets smaller from the first to third molar. Every molar has four or five cusps, is shorter and blunter fit than other teeth and gives an expansive surface to chewing and grinding strong masses of food.

The teeth of the upper curve are called maxillary teeth (upper teeth) because their roots are inserted inside the alveolar procedure of the maxilla (upper jaw). Those of the lower curve are called mandibular teeth (lower teeth) as their roots are installed inside the alveolar procedure of the mandible (lower jaw). Every curve contains 16 teeth and is partitioned into a right and left quadrant. Teeth are depicted as being situated in one of the four quadrants. A human gets ordinarily two arrangements of teeth amid a lifetime. The essential set, which more often than not comprises of 20 teeth and a perpetual set which for the most part comprises of 32 teeth. In every quadrant, there are eight perpetual teeth: two incisors, one cuspid, two bicuspid, and three molars [13], see Figure 2.3.

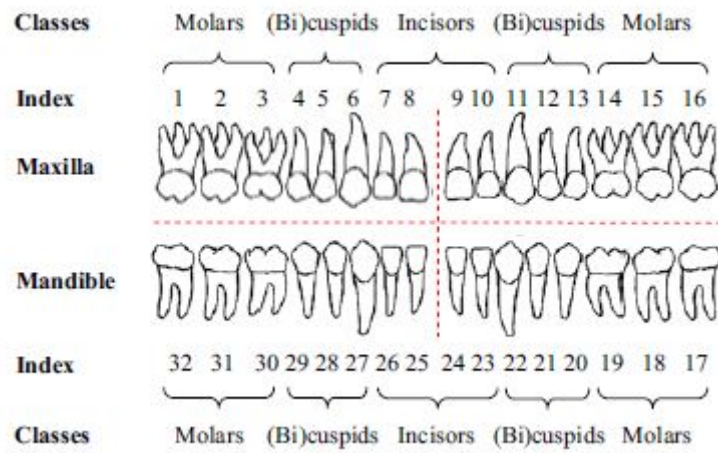


Figure 2.2: Universal Numbering System used on a standard dental chart for a full set of adult teeth.

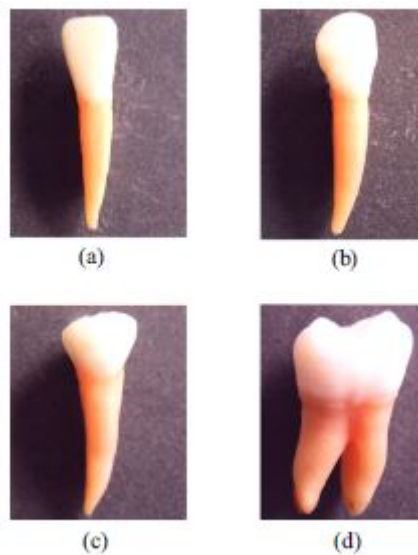


Figure 2.3: Photographs of different types of teeth
 (a) Adult mandibular right central incisor, (b) Adult mandibular right cuspid, (c) Adult mandibular right first bicuspid, (d) Adult mandibular right second molar.

2.4 Dental Restoration

Dental restoration refers to the reproduction of missing tooth structure using manufactured materials. There are various advantages for tooth reclamation which incorporate health benefits (the fortifying of influenced teeth to avoid further tooth disintegration, the substitution of harmed and/or missing teeth) and aesthetical preferences (supplanting of a harmed tooth with a more natural, more beneficial looking tooth) [14].

There are two ways to perform dental restorations:

- Direct restorations are fillings which are put quickly into a readied hole into the tooth. Regular direct rebuilding materials incorporate dental amalgam, composite gums and glass ionomer cement (tooth-shaded materials that bond chemically to dental hard tissues)
- Indirect restorations are specially crafted fillings that are made in a dental research facility as per a specialist's remedy. Regular indirect restorative materials includes acrylic, porcelain, zircon, gold and different metals.

Different Types of Dental Restorations are [14][5] :

- Amalgam fillings: Amalgam is created by blending mercury and different metals is still the most normally utilized filling material since it is tough, simple to utilize and reasonable.
- Composite resin fillings: A tooth-shaded filling material utilized essentially for front teeth. Although cosmetically superior, it is generally less tough than different materials.
- Cast restorations: A technique that uses a model of the tooth (an impression) to make a throwing which replaces missing parts (e.g. crowns).
- Crowns (or caps): The artificial covering of a tooth with metal, porcelain of porcelain intertwined to metal. Crowns cover teeth weakened by rot or seriously harmed or chipped.
- Inlays and onlays: An inlay is a strong filling cast to fit the missing part of the tooth and solidified into spot. An onlay is a fractional crown and covers one or more tooth cusps.
- Implants: A dental implant is a artificial tooth root surgically set specifically into the jawbone where a tooth is absent. They are utilized to support dental prosthesis from single crowns to full denture.

2.5 Types of Dental Radiographs

There are three major types of dental radiographs called panoramic, periapical and bitewing images.

2.5.1 Panoramic Dental Radiographs

A panoramic dental radiograph is an expansive, single x-ray image that demonstrates the firm structure of teeth and face, see Figure 2.4. This sort of radiograph varies from the others since it is totally extra oral, which implies that the film stays outside of the mouth while the machine shoots the bar. A much more extensive territory than any intra oral film can be seen on the radiograph including hard tumors, growths and the position of the knowledge teeth and in addition structures outside the mouth like the sinuses (air-filled holes in a skull bone) and the temporomandibular joints that pivot the mandible to the skull.

The panoramic dental radiograph is a lesser resolution image than intraoral films. This implies that the single structures which is shown up on them, for example, the teeth and bones, are to some degree fuzzy and skeleton like caries (decay of tooth) are imaged without the fine details observed on intraoral films. They are not viewed as adequate for the determination of rot, and should be joined by an arrangement of bitewing radiographs in the event that they are to be utilized as an method for complete diagnostic purpose. In addition to dental and medical uses, panoramic films are pretty good in forensic works[15] .



Figure 2.4: Panoramic dental radiograph including dental restorations

2.5.2 Bitewing Dental Radiographs

A bitewing dental radiograph is taken mainly of the back teeth (molars and bicuspids) while the patient bites the teeth together; thus, the film contains images of both, the upper and lower teeth, see Figure 2.5 (a). Every one of the three components (the teeth, the film, and the x-ray beam) are improved to furnish the maximum precise shadow conceivable. The film and the teeth are laterally parallel, and bar is pointed straight forwardly at both at an angle of 90 degree. In this manner, bitewing films bear the cost of the most precise illustration of the genuine state of the teeth and related structure, for example, decay, fillings, bone levels and state of nerves [15].

2.5.3 Periapical Dental Radiographs

A periapical dental radiograph is shot from a point in which the three components (the teeth, the film, and the x-beam bar) are not as a matter of course adjusted parallelly. They can demonstrate the entire tooth, including the crown which is above and the root which is underneath the gumline, see Figure 2.5 (b). Some contortion is acquainted intentionally with make sure that the shadow of the whole tooth or teeth falls on the film. This is done on the grounds that in numerous occasions, the space accessible in the mouth or the shape of the top of the mouth won't allow parallel situation of the film [15].



Figure 2.5: Bitewing and periapical dental radiograph
(a) Bitewing and (b) periapical dental radiograph [16]

2.6 Literature Survey

As per specialists from the Criminal Justice Information Services Division (CJIS) of the FBI, there are 100,000 unsolved instances of missing persons at any given point in time. In 1997, The CJIS of the FBI made a dental task force (DTF) whose

objective was to enhance the usage and adequacy of National Crime Information Center's (NCIC) for missing and unidentified persons (MUP) documents. The DTF prescribed in the production of a Digital Image Repository (DIR) and an Automated Dental Identification System (ADIS) with objectives and targets like the Automated Fingerprint Identification System (AFIS) however utilizing dental attributes rather than fingerprints.

As per these facts, much work has been done in the field of dental biometrics:

- Abdel-Mottaleb and Mahoor [17] proposed a mechanism to acquire the index of the teeth in the bitewing dental images by utilizing Bayesian distribution. This algorithm is concerned of arrangement of teeth in the jaw and assigns a number taking into account the Universal Numbering System. A noteworthy restriction of their technique is that bitewing pictures contain just molars and bicuspid teeth. It also checks that there is no missing teeth in the radiographs, which is not genuinely valid. In the event that this presumption is not fulfilled, registration fault will happen.
- Samy, Salam, Nabil and Nazmy [18] proposed an arrangement of upgrading methods to enhance the low quality of dental radiographs utilizing morphological calculations, for example, bottom and top hat transform and flood fill algorithms. These systems give pictures that can be divided utilizing morphological techniques. Every tooth is removed from an arrangement of teeth utilizing the watershed procedure. The coordinating procedure relies on upon geometric components and on a mark which is invariant to interpretation, scaling and revolution, and is created by a pulse coupled neural network (PCNN).
- Fahmy, Ammar, Nassar and Said [7] proposed a technique for the division of dental radiographs by utilizing the algorithm based upon the morphological filtering and a modified 2-D wavelet transform. It's business locales the issue of distinguishing every single tooth and method to extract the shapes of every tooth. Along these lines, they perform fundamental projection of vertical and horizontal lines to recognize the limits of the tooth.
- Hong Chen and Anil k jain [16] proposed the algorithm for the enrollment of the dental chart to dental radiograph and additionally a technique for coordinating dental x-ray pictures for human recognizable proof . More detailed description of these algorithms are displayed in the following two segments.

Registration of Dental Atlas in Radiographs for Human Identification (Anil K. Jain, Hong Chen) [16]

Enlisting a dental radiograph to the dental atlas (Universal Numbering System) gives the position and index of every tooth in the radiograph. This is utilized to set up the correspondence of teeth while coordinating two dental radiographs. The proposed strategy deals with every one of the three sorts of radiographs (bitewing, periapical and panoramic images). The primary phase of the algorithm is to classify the teeth in the radiographs into molars, (bi)cuspid and incisors. Therefore, three Support Vector Machines (SVM) are fused to get great order precision. The second stage uses a Hidden Markov Model (HMM) to represent the dental atlas. The observed sequence in the radiographs are enlisted to the dental atlas via scanning for the way that has the biggest likelihood of event. Results of this technique can be seen in the Figure 2.6.

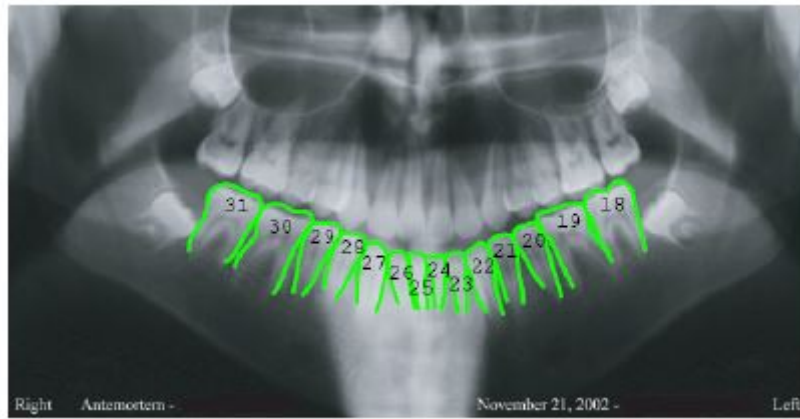


Figure 2.6: Registration of the dental atlas to a panoramic dental radiograph

Matching of Dental X-ray Images for Human Identification (Anil K. Jain, Hong Chen) [19]

The objective of this work addresses the issue of robotizing the procedure of recognizing individuals taking into account their dental radiographs. The system comprises of two fundamental stages: the feature extraction stage, where the tooth shapes are extracted, and the feature matching stage, where the extracted tooth contours are compared against tooth contours stored in the database. The initial step is to fragment the radiograph into block such that every block has a tooth in it, see Figure 2.7 (a). To extract the tooth, see Figure 2.7 (b), contour a probabilistic model is utilized to describe the distribution of tooth and background pixel. After that, transformation adjust the contour to right imaging geometric varieties.

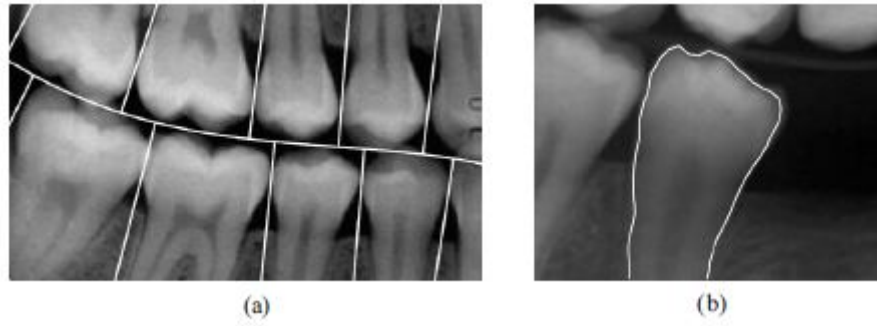


Figure 2.7: Feature extraction of dental radiographs
 (a) Result of separating the teeth into blocks.(b) Extracted tooth contour [19].

The dental works, which appears as bright region in the radiographs, are striking elements for subject identification. To extract the contour of the dental work, they utilized the intensity histogram of the tooth picture and approximated it with a blend of Gaussians model, where the Gaussian part with the biggest mean value compares to the pixels connected with the dental work. Anisotropic diffusion is used which smoothes the pixels inside every region while preserving the boundary between the regions, see Figure 2.8.

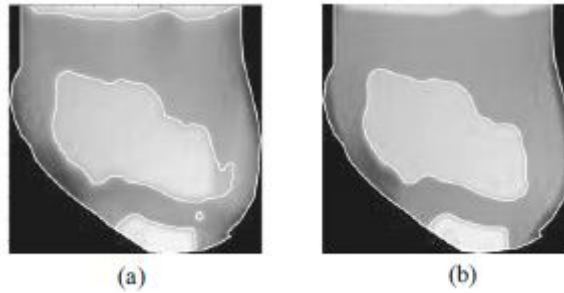


Figure 2.8: Tooth including the extracted contours of the dental works before and after using anisotropic diffusion to smooth the pixels inside each region [8]

Finally, matching scores for the tooth and the dental works contours are computed. The combination of these matching scores measures the uniformity between the given two radiograph. A candidate list of potential matches is created for human specialists to make further decision.

Some more Analysis on Dental Biometrics :

Dental Identification by Comparison of AM and PM dental radiograph: Influence of Operator qualifications and Cognitive bias. -Vilmi Pinchi, Gian-Aristide Cecelia Vincenti Norelli Fabio Caputi, Francesco Pradella, Gian franco fassino

Matching was done at 3 increasing levels of difficulty.

- low difficulty,
- medium difficulty,
- high difficulty

Identification test to 78 independent operators. All 78-operators completed the identification test, which consisted of 42 PM IXR's and 16 AM OPG's. Accuracy and Specificity for different operators group-

ER 0.76-0.70

ML 0.76-0.88

STU 0.89-0.82

DENT 0.87-0.97

DEN-TRA 0.88-0.92

FOR 0.97-1

Database used : OPG's of 16 patients, 42 intraoral radiographs (30 apical radiograph & 12 bitewing) were selected as PM intraoral radiograph (PM-IXR's) and 16 AM OPG's.

Conclusion : Operators with dental training including the pregraduate dental students, are considerably more accurate than those with a medical degree.

Dental Biometrics: Matching Dental X-rays for Human Identification.
-Anil K jain,,Hong Chen,Silviu Minut

Pixel classification is used for contour extraction.

- Classify background pixel and teeth pixel.
- Classify edge points and non-edge points.

- Connect the edge points to be the contour.

Variation in view angle was small so affine transformation works well for matching radiographs. Genuine Image were found to have smaller matching distance (md) than the imposter image.

Database used : AM radiographs consisting of 130 images.

2.7 Problems using Dental Biometrics

Dealing with dental biometrics leads to several problems:

- Unlike to other biometric features (e.g. facial recognition or iris detection) dental components do change after some time, e.g. teeth and dental restorations efforts can change their appearance or can be missing altogether after the AM radiographs are obtained. Thus, dental based identification is viewed as less reliable than other biometric method yet might be the only accessible biometric technique in certain cases (e.g. fires accident) [20].
- The feature extraction is a tough problem for dental radiographs matching process, especially if they have a poor quality and some tooth or dental restorations contours cannot be correctly detected.
- Dental radiograph may be obtained at different viewing angle which may affect the matching process of a postmortem (PM) radiograph with an antemortem (AM) radiograph [16].
- It is very much difficult to create a dental table, which is currently done by forensic experts manually, because each tooth has to be classified and preprocessed before it can be further processed.
- Different dental radiograph have distinct orientations, resolutions and luminance characteristic, based on the X-ray machine and the dental expert who took it [21].

Chapter 3

Proposed DRS using Active Contour Model

3.1 Active Contour Model

3.1.1 Overview of Active Contour Model :

Active contour Model, or the snake model, are computer created curves which moves within the image to detect the object boundaries. It's 3-D version is commonly known as the active surfaces or deformable models in literature. We have built up another sort of snake that allows the snake to begin a long way from the object which is to be detect, yet it converges towards the object, and constrains it into the boundary of the object. The new snake depends on another type of external force field, called GVF , or gradient vector flow. This field force is computed as a spatial diffusion of the gradient of an edge map got from the images. This calculation causes diffused forces to exist a long way from the object, and fresh constrain vectors close to the edges. Consolidating these strengths with the standard internal powers yields an effective computational object: the GVF snake (2D), or the GVF deformable model (N-D). We have tested on different images regarding GVF on line drawings and grayscale pictures, including image of Teeths.

Main objective: Active Contour model are used for image segmentation in which a curve is allowed to deform iteratively to partition the image into region i.e. object and non-object. Active contours are mostly implemented to extract the shape of an irregular geometrical structure. The primary demerit of this model is that they are slow to compute.

Introduction : Snakes or the active contours are PC created curve that moves within the image to detect object boundary .They are regularly utilized as a part of computer vision and image examination to locate and recognize the objects and to

portray their shape. For instance, a snake may be utilized to automatically locate a produced part on a sequential construction system; one may be utilized to discover the diagram of an organ in a medical picture; or one may be utilized to consequently recognize characters on a postal letter. We have built up another sort of snake here for the Image Analysis.

3.1.2 Method :

The snake, which is known as the gradient vector flow (GVF) snake, starts with computation of a field of force, called the GVF forces, over the picture domain. The GVF forces that are used to drive the snake are modeled as a physical object having a tendency to both bending and stretching, towards the boundaries of object. The GVF forces are computed by applying generalized diffusion equation to both components of the gradient of an image edge map.

Gradient Vector Flow (GVF)

- Detects the shapes with boundary limits.
- Vast capture range.

Model for GVF snake: Snakes Energy Equation

- Parametric representation of curve $v(s) = (x(s), y(s))$
- Energy functional consists of three terms

$$\varepsilon = \int [\varepsilon_{int}(v(s)) + \varepsilon_{img}(v(s)) + \varepsilon_{con}(v(s))] ds \quad (3.1)$$

- Where the snake is parametrically defined as $v(s) = (x(s), y(s))$
- $E_{internal}$: Internal spline energy caused by stretching and bending.
- E_{image} : Measure of the attraction of image features such as contours.
- $E_{constraint}$: Measure of external constraints either from higher level shape information or user applied energy.

Internal Energy

$$\varepsilon_{int}(v(s)) = (\alpha(s)||v_s||^2 + \beta(s)||v_{ss}||^2)/2 \quad (3.2)$$

- First term is “membrane” term – minimum energy when curve minimizes length(“soap bubble”)
- Second term is “thin plate” term – minimum energy when curve is smooth.

- Control α and β to vary between extremes
- Set β to 0 at a point to allow corner
- Set β to 0 everywhere to let curve follow sharp creases – “strings”

Image Energy

- Variety of terms give different effects
- For example,

$$\varepsilon_{img} = w \cdot |I(x, y) - I_{desired}| \quad (3.3)$$

minimizes energy at intensity $I_{desired}$

Edge Attraction

- Gradient-based:

$$\varepsilon_{img} = -w \cdot \|\nabla I(x, y)\|^2 \quad (3.4)$$

- Laplacian-based:

$$\varepsilon_{img} = w \cdot |\nabla^2 I(x, y)|^2 \quad (3.5)$$

Corner Attraction

- Can use corner detector we saw last time
- Alternatively, let $q = \tan^{-1} I_y / I_x$ and let n be a unit vector perpendicular to the gradient. Then

$$\varepsilon_{image} = w \cdot \left| \frac{\partial \Theta}{\partial n_{\perp}} \right| \quad (3.6)$$

Constraint Forces

- Spring

$$\varepsilon_{con} = k \cdot \|v - x\|^2 \quad (3.7)$$

- Repulsion

$$\varepsilon_{con} = \frac{k}{\|v - x\|^2} \quad (3.8)$$

Evolving Curve

- Computing forces on v that locally minimize energy gives differential equation for v
 - Euler-Lagrange formula

$$\frac{d^2}{ds^2} \left(\frac{\partial \varepsilon}{\partial \ddot{v}} \right) + \frac{d}{ds} \left(\frac{\partial \varepsilon}{\partial \dot{v}} \right) + \frac{\partial \varepsilon}{\partial v} = 0 \quad (3.9)$$

- Discretize v : samples (x_i, y_i)
 - Approximate derivatives with finite differences
- Iterative numerical solver

Problem with GVF snake:

- Very sensitive to parameters.
- Slow. Finding GVF field is computationally expensive.
- Initial location dependent.

Applications of snakes :

- Image segmentation particularly medical imaging community (tremendous help).
- Motion tracking.
- Stereo matching (Kass, Witkin).
- Shape recognition.

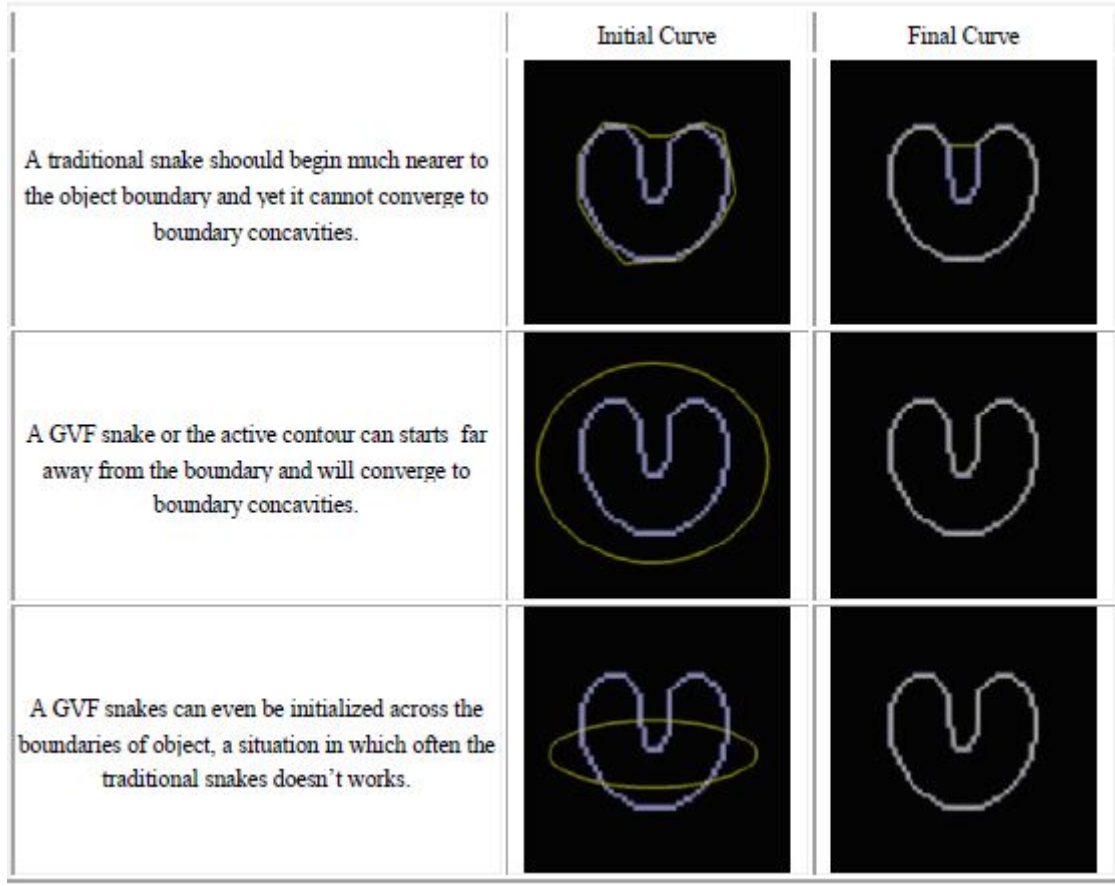


Figure 3.1: comparison between traditional curve and GVF snake

Comparison between traditional and GVF Snake:

3.2 Motivation

Our main objective is to identify the deceased using the dental radiographs. And for the system to execute the process, first and the important part of the process is the proper shape extraction of the tooth. But detecting the shape of the tooth wasn't a easy task. Tooth doesn't have a simple geometrical shape, that's why we have to go for a method which could give the desired output for this complex shape. A simple curve would not be working in this case. Snake model clearly defines our goal in which the energy curve has the ability to deform and completely converges around the object to give the proper shape of the object.

3.3 The Proposed Methodology

In this research a modified version of Active Contour Model has been implemented. We are using a matrix of initialization instead of a single initialization point. The initialization will be the major factor for determining our results. Better the initialization, more accurate and better will be the result or the output. The grid of the initialization serves as the key points in determining the shapes of the teeth. The initialized points must lie on the edges of the object to detect its contour. The other factor determining the results was the number of iterations. The number of iteration carried out on an input image must be the minimum value upto which the curves constrains over the image and no further change is observed in the output. Having large value of iteration will only increase the time complexity of the algorithm. Therefore it's value must be optimized to give the desired output based on the size of the input image. The proposed algorithm was implemented on a set of about 20 teeth radiographs and the output was very much desirable giving the proper shape and structure of the teeth. The complex shape of the tooth was very well extracted using this new algorithm. The output was very much informative and could easily be utilized for further procedure i.e. the matching process.

3.3.1 Proposed Algorithm Snake:

Inputs: Image I and a chain of points on the image P_1, P_2, \dots, P_n .

F the least fraction of snake initial points which must move in each iterations and $U(p)$ a small neighborhood of p and d (the average distance).

1. For each $i = 1, \dots, N$, find the location in $U(p_i)$ for which energy functional is least and move the control point p_i to that point.
2. For each $i = 1, \dots, N$, calculate the curvature and look for local maxima.

$$k = ||p_i - 1 - 2p_i + p_i + 1||^2 \quad (3.10)$$

Set $\beta_i = 0$ for all p_i at which the curvature has a local maximum or exceeds some user-defined value.

3. Update the value of the average distance, d.

3.3.2 Initialization Mask

Matrix of initialization points

The initialization is the most important factor in determining the contour of the teeth. It varies from image to image. The seed points must lie on the edge of the object to detect its boundary.

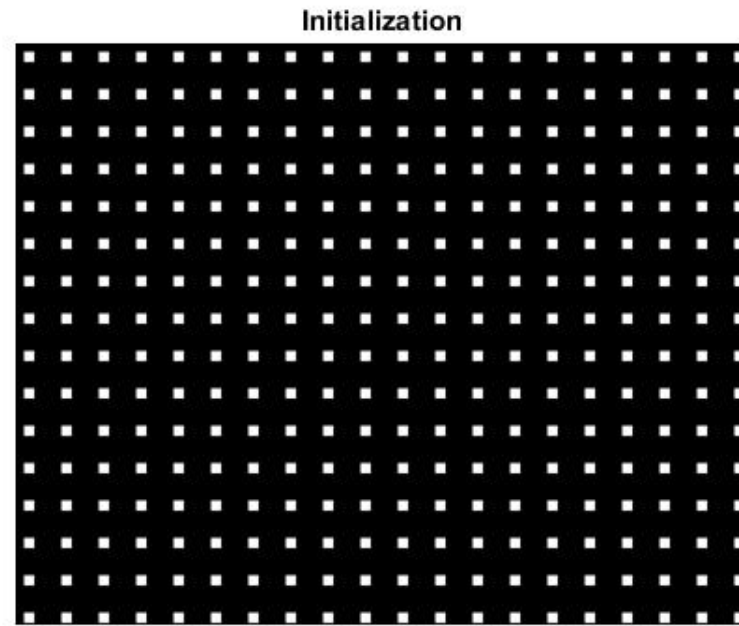


Figure 3.2: Initialisation 1

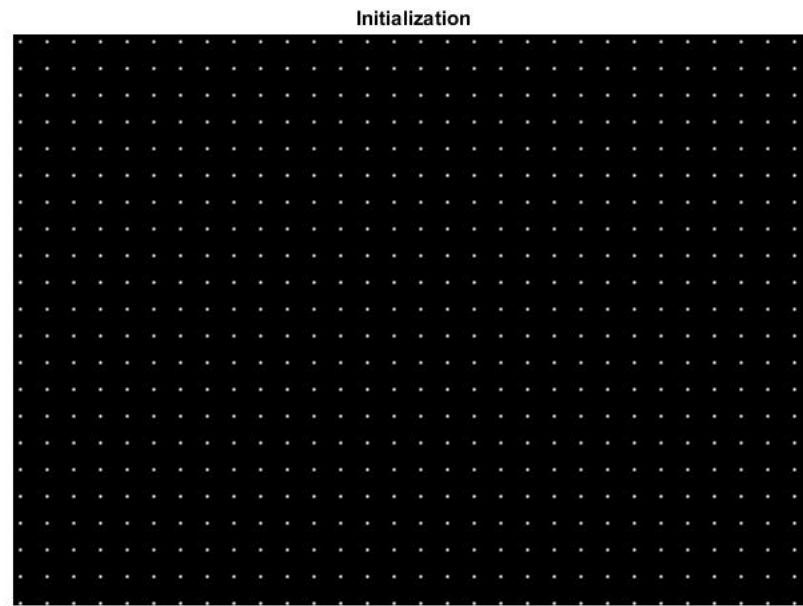


Figure 3.3: Initialisation 2

3.4 Experimental Setup

All experiments relevant to the thesis were carried out on Intel(R) Core(TM) i7-3537U CPU @ 2.00GHz 2.50 GHz. 64-bit Operating System,x64-based processor with 8.00 GB RAM. The experiments are simulated using Matlab® Version 2.1 (R2015a).

3.5 Results

The proposed method works very well on dental radiographs and is capable of giving the desired output with well defined contours.

Some of the experimental results on few images are follows:

Input image : A Simple Radiograph Image

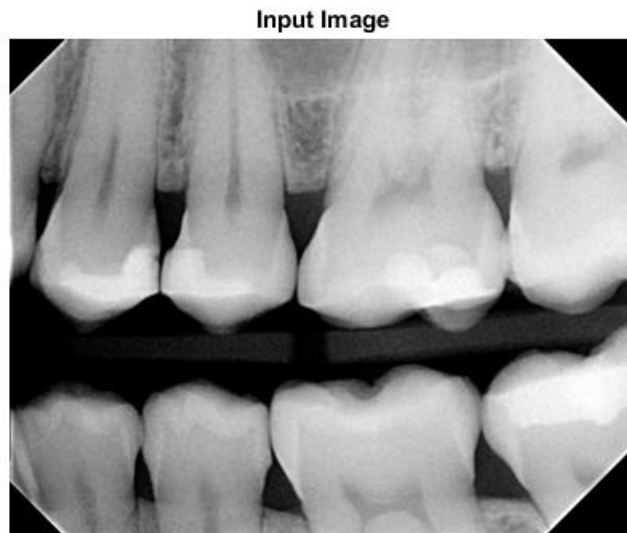


Figure 3.4: Sample input image (1)

This is the output observed during the code implementation at 30 iteration. we could see that initialization starts their functionality with a tendency to deform and stretch to detect the edges of the object.

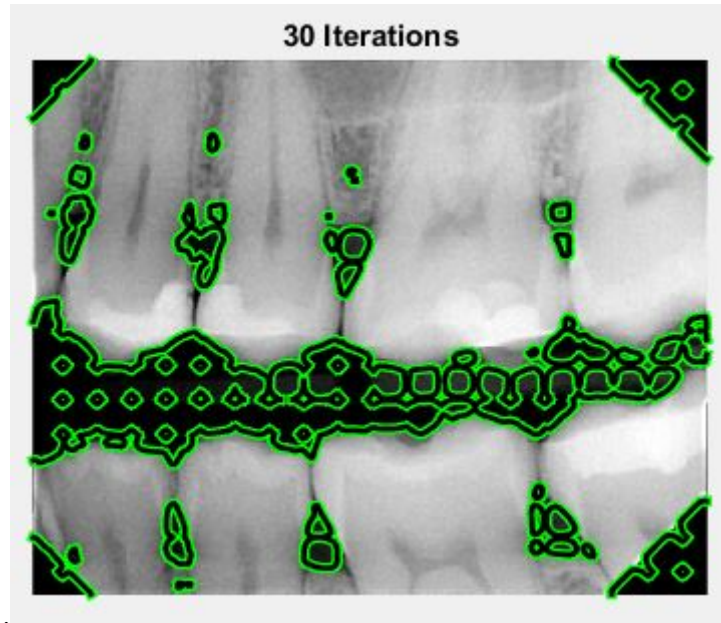


Figure 3.5: Output at 30 iterations

This figure is the output after the total number of iteration (900) has been executed. We could see that the curves have been well fitted on the teeth and are properly adjusted on the edges of the tooth forming the contour of the teeth

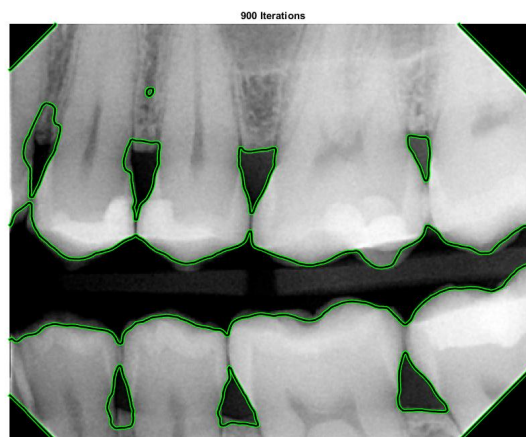


Figure 3.6: Final contour after full iterations

This is the final output of the given radiograph clearly demonstrating the object and the non-object fraction of the image. The output is very much desirable and could be used in later steps of dental biometrics.

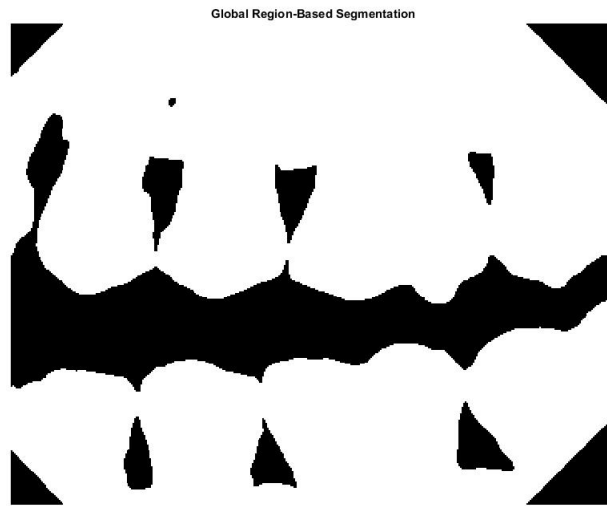


Figure 3.7: Final output (1)

Some more experimental analysis on different images :
Input Image

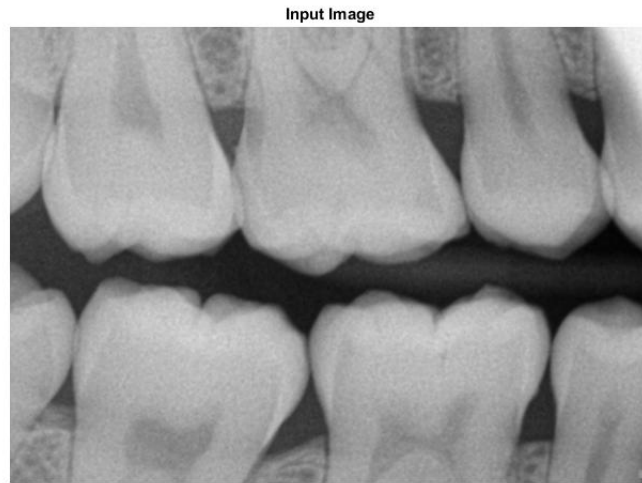


Figure 3.8: Sample input image (2)

After 25 iterations :

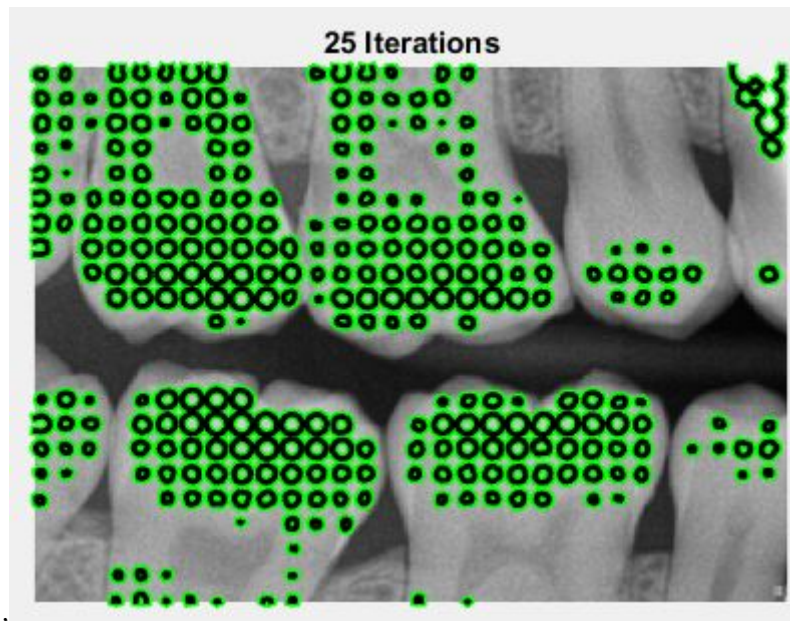


Figure 3.9: Output at 25 iterations for sample input image 2

Final contour detected after the iterations which have been successfully executed

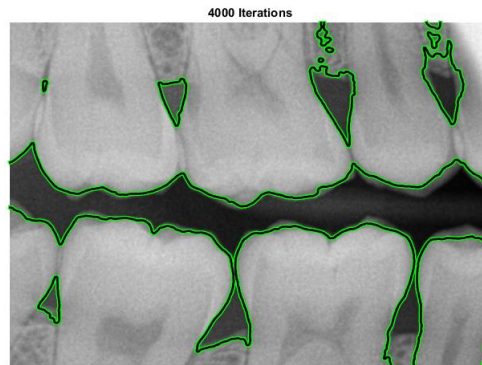


Figure 3.10: Output at 25 iterations for sample input image 2

Final output representing the binary form of the image showing the object and the non-object part of the image

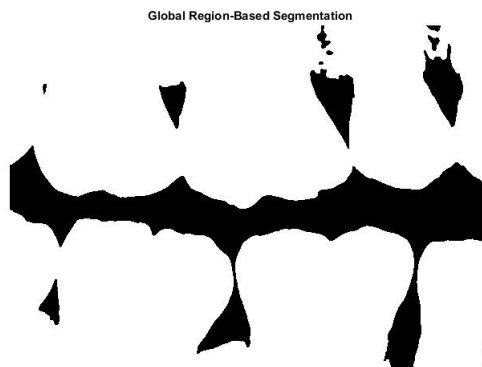


Figure 3.11: Output at 25 iterations for sample input image 2

The proposed method was implemented on a set of 20 radiographs. The results were upto the mark and were very informative clearly distinguishing the object from the non-object.

Conclusion:

- The minimization of the energy function is too sensitive to the initial seed of the snake. This means that if the initial radius of the snake is small then boundary of object will not be effectively captured.
- The important weights of the internal and external forces, in the energy objective function affect snake performance. There is a fine tuning process that is required such that the results to be acceptable.
- The number of pixels that snake contains plays a critical role in the minimization process. If the number of pixels is small the snake will not be able to capture the boundaries of the regions of our interest.

Chapter 4

Conclusion and Future Work

Biometrics is a relatively new technology, which is being deployed in public and private sector applications and, thus, has received much attention in the last years. Dental bio-metrics is used in the forensic medicine to identify individuals based on their dental characteristics by comparing unlabeled post-mortem with labeled ante-mortem radiographs.

The thesis approaches towards developing an automated system for Human Identification using Dental radiographs. In this thesis an effective method of contour extraction of teeth is proposed. The proposed method is a modified version of the snake model for contour extraction. The proposed method is experimented against X-ray radiograph of teeth to extract the contour shape of the teeth. The output were very much desirable and reliable clearly demonstrating the contour of the teeth. The output images could easily be processed for further evaluation and matching process.

Currently an open database of dental radiographs is not available so we have not tested it on a large datasets and the matching part. It is working fast and delivering a perfect result for contour extraction of the dental images of the teeth. The proposed approach efficiently detects annular region defining the contour of the teeth.

The approach method is a modified version of the Active Contour Model or the Snake Model Which is accepted with few limitations and drawbacks.

To conclude with this thesis, the proposed method has been analysed on few radiographs and the results are much welcomed. Using these results further procedure can be executed.

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